SCHOOL OF
CIVIL ENGINEERING

INDIANA
DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT

JHRP 86/1 — 1

MICROCOMPUTER IMPLEMENTATION OF SANTA: A PERSONNEL MANAGEMENT MODEL

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Final Report

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A PERSONNEL MANAGEMENT MODEL

TO:	H. L. Michael, Director Joint Highway Research Project	January 29, 1986
		Project: C-36-67T
FROM:	Jeffrey R. Wright Assistant Professor	File: 9-11-20

Attached is the Final Report on the JHRP Study entitled, "Microcomputer Implementation of SANTA: A Personnel Management Model." The research was conducted by Steven C. Egly, Graduate Assistant in Research, under the direction of Professor J. R. Wright.

The focus of this research was the implementation of the computer-based personnel management model known as SANTA (Systematic Analysis of Noninferior Transfer Assignments). The model is a multiobjective integer program that can generate the complete and precise tradeoff curve between the objectives of minimizing total distance that the reassigned workforce must travel from their respective homes to one of many site locations, and minimizing the maximum distance that any one worker must travel. Details of the model structure and solution procedure are presented together with the results of an actual application.

This report is forwarded for review, comment and acceptance by the IDOH as fulfillment of the objectives of the study.

Respectfully submitted,

J.R. Wright

J. R. Wright
Assistant Professor

JRW/mlr

cc:

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Final Report

MICROCOMPUTER IMPLEMENTATION OF SANTA: A PERSONNEL MANAGEMENT MODEL

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Project No.: C-36-67T

File No.: 9-11-20

Prepared as Part of an Investigation

Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

in Cooperation with the

Indiana Department of Highways

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West Lafayette, Indiana

January 29, 1986

Microcomputer Implementation of SANTA: A Personnel Management Model

Jeff R. Wright and Steven C. Egly

The focus of this research was the implementation of the computer-based personnel management model known as SANTA; for Systematic Analysis of Noninferior Transfer Assignments. The model is a multiobjective integer program that can generate the complete and precise tradeoff curve between the objectives of minimizing total distance that the reassigned workforce must travel from their respective homes to one of many site locations, and minimizing the maximum distance that any one worker must travel. System constraints include demand requirements for workers at each site and the limited availability of state-owned vehicles that may be issued to workers assigned to remote sites. Details of the model structure and solution procedure are presented together with the results of an actual application. A complete users guide for model operation is provided as an appendix to this report.

The quality of services provided by public institutions is often very difficult to quantify. In contrast to the private sector where engineering management objectives are usually specified in terms of economic efficiency, government agencies strive to provide the "best" level of service possible as measured by public well-being and safety. These performance criteria are generally difficult to quantify for most public service activities. The removal of snow and ice from the intrastate highway system is a good case in point.

In developing a strategy for winter season snow and ice control, the goal is to provide efficient service within the constraints on available resources, plowing and abrasive spreading equipment, sand and salt supplies, and maintenance personnel. While holding down overall cost is a primary consideration, the safety of the public is the major objective.[1] Public safety in this context has two distinct, but related components: 1) the condition of the road surface, and 2) the performance of the snow removal fleet during the operation. An effective snow removal operation is one that provides rapid and orderly snow removal and abrasive application without excessive interference with public transportation activity.[2,3]

As with many public-sector management operations, snow and ice control may be viewed as a series of discrete sub-problems: 1) the locating and sizing of facilities for storage of abrasives, maintenance vehicles and equipment; 2) the partitioning of the target roadway network into sub-areas that are manageable from the standpoint of administration; 3) the definition and assignment of vehicles and crews to service routes; and 4) the assignment of individuals to job locations. While other decompositions of the problem have been proposed,[4-8] they tend to focus on the optimal design of service routes and the location of storage sites, neglecting the importance of personnel management in general, and fleet mobilization in particular. In contrast, the present work looks at the problem of assigning individual workers (drivers and radio operators) to worksites in such a way that when a snow emergency occurs, service may be initiated as efficiently and as rapidly as possible.

The Problem

It is the responsibility of the Indiana Department of Highways (IDoH) to provide for the removal of snow and ice from the Indiana intrastate highway system during the winter months. The goal is to conduct snow removal as efficiently as possible while holding cost to a minimum. Efficiency is a function of the rapid and orderly mobilization of a fleet of snow removal vehicles (*snowplows*) and a force of trained drivers and radio operators.

Snow removal is administered through the maintenance division of each of the six district offices of IDoH. Prior to the start of each snow season, available personnel are assigned to one of many *unit locations* for the duration of the winter months. Each unit location houses snow removal equipment and supplies necessary to maintain one or more *snow routes*. The number of workers required at each unit location depends on the number, length and priority of the snow routes maintained by that site and does not fluctuate dramatically from season to season.

The maintenance departments do not have a sufficient work force to provide drivers and radio operators to adequately staff all site locations. However, other IDoH divisions, such as the construction division, do not have sufficient work during the winter months for their employees.

Consequently, to avoid costly seasonal hirings and firings, IDoH *reassigns* summer construction workers to winter snow removal teams; a worker assigned to Unit No. 14 for construction during the summer may be assigned to unit No. 5 for snow removal during the winter.

The efficiency of snow removal and the overall cost of the operation depend heavily on this reassignment profile. Assigning drivers to units that are geographically "close" to their residences means that the time to the initiation of snow removal is short. Furthermore, a shorter distance from home to work increases the chances that a driver will be able to report to work during a snow emergency.

Overall cost is related to distance, but in a less obvious manner.

is not to his nearest unit *and* that assignment is more than 15 miles from his home station, he/she must be given use of a state vehicle. An example of this re-assignment policy is shown graphically as Figure 1. Consider two workers A and B. The distance from the residence of each worker to each site location is known. Assuming some maximum allowable assignment distance is specified -- *No worker shall have to travel more than D miles to work* -- a set of eligible site assignments may be determined. Suppose that the eligible site assignments for Worker A are sites 1 and 2, and for Worker B sites 1, 2, 3, and 4. If Worker A is assigned to site 2, a vehicle would not be issued even though the travel distance is beyond the 15-mile limit because it is still the closest eligible site. Similarly, the assignment of Worker B to site 4 would not require issuance of a vehicle as this site, though not his/her nearest, is within the distance limit. The policy may be applied in this manner to all possible worker assignments. By assigning workers to sites that do not require issuance of a vehicle, the cost for providing transportation may be avoided. Note that if the issuance of one additional vehicle does not result in a real cost or loss of opportunity, this issue is treated more properly as a system constraint.

The general snow removal personnel reassignment problem may now be stated:

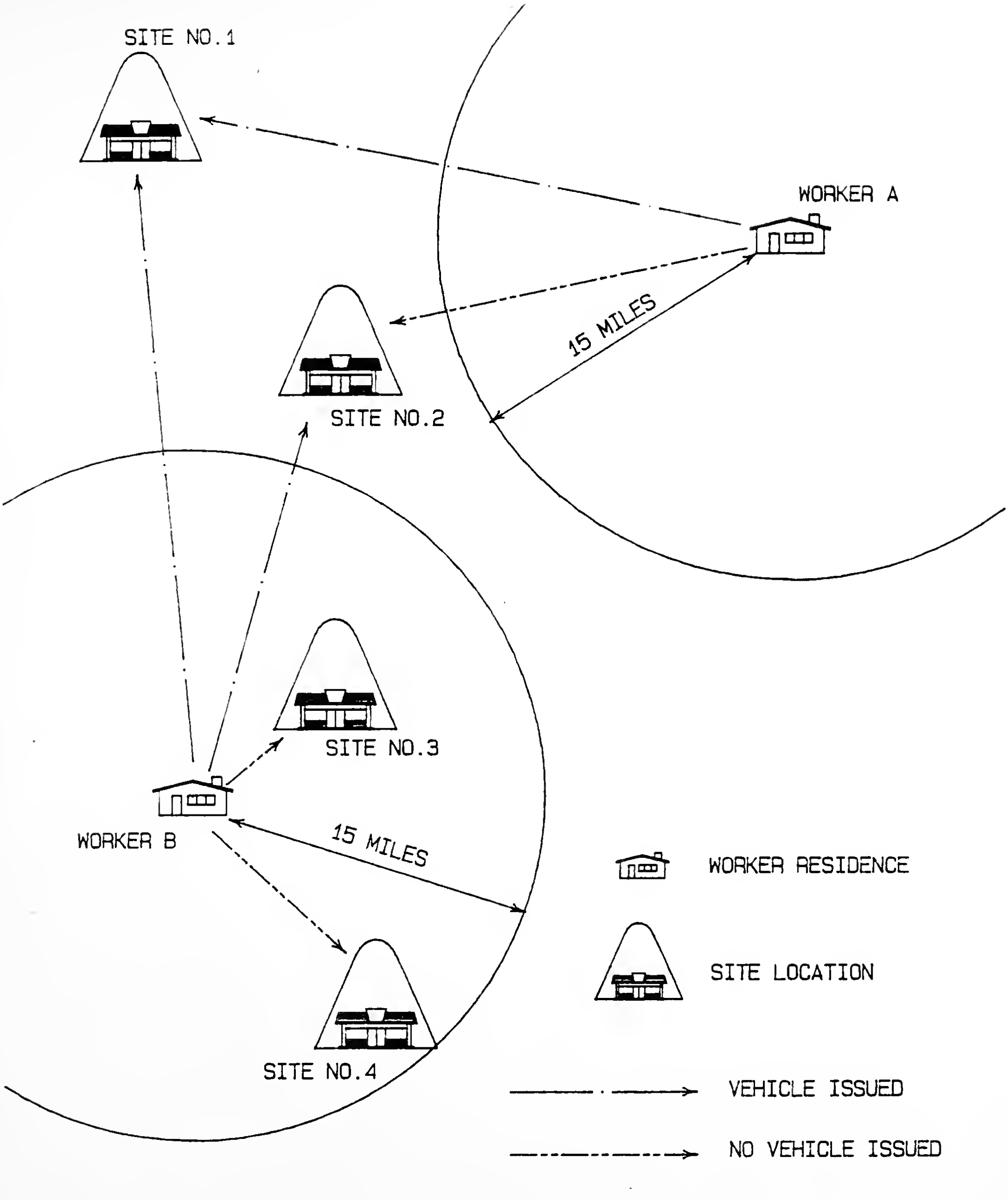


Figure 1. Schematic representation of winter personnel transfer problem

> *"Find that strategy for the reassignment of available personnel to snow removal units during the winter such that the total distance traveled by all workers to their respective job site is as small as possible while keeping the number of vehicles assigned to workers as small as possible."*

In general, the strategy that minimizes total distance will not be the same as the strategy that minimizes the assignment of vehicles. Most workers live more than 15 miles from most sites. The distance saved by assigning one worker to his/her closest site (thus avoiding issuance of a vehicle) is likely to be less than the added distance another person will have to travel to cover the original assignment.

The objectives of minimizing total one-way travel distance and minimizing total vehicles issued to workers do not address one important aspect of public-sector engineering management; that of equity in the provision of services. The solution that minimizes total or average travel distance may have a great variation in assigned travel distances. If the average travel distance is, say 45 miles, a solution that assigns Worker A to a site 5 miles away and worker B to a site 85 miles away would be just as "good" as one that assigns both workers to sites 45 miles away from their homes. And yet these two solutions are clearly not identical in their impact on overall level of service.

One approach to the specification of an equity objective is to seek that reassignment strategy that makes the deviation in travel distance about the mean travel distance as small as possible. Alternately, one might try to minimize absolute deviation in travel distance. While both of these objectives would result in solutions that may be more equitable than that which minimizes total travel distance, they would tend to promote assignment strategies that are inherently inefficient; workers might be assigned in such a manner that, in order to balance travel distances, they would pass each other as they drive to work.

A more acceptable equity objective would be one that minimizes the travel distance of the person who must travel the greatest distance to work; *minimize maximum travel distance*. While this objective is also likely to be in "conflict" with that which minimizes total distance, it is also likely to be much more acceptable to both workers and management. Including such an equity objective in the model and treating the limit on available vehicles as a system

constraint, we offer a more realistic statement of the snow removal personnel reassignment problem:

> *"Find that strategy for the reassignment of available personnel to snow removal units during the winter such that the total distance traveled by all workers to their respective job sites is as small as possible while keeping the maximum distance traveled by any one worker as small as possible without assigning more vehicles than are available."*

The problem may be complicated by other factors. Some individuals may be better drivers than others. Some may have difficulty driving at night. Some may wish to be assigned in such a way that they are issued a vehicle. Some may not wish to be issued a vehicle. Some may feel that they have seniority. Some may be assigned to units much further away than others living near the same location. Though not explicitly addressed in this work, each of these factors may need to be considered in developing an optimal reassignment strategy.

The Model

A variety of analytical methods have been proposed for addressing problems of personnel management and scheduling in the public sector. These applications have included problems such as scheduling mass transit crews,[9,10] deployment of law enforcement personnel,[11,12] scheduling of work crew shifts,[13-19] school bus routing,[20] refuse collection scheduling,[21,22] and the scheduling of safety inspections.[23,24]

As varied as the applications are the modeling procedures that have been employed to address these problems. Both linear[22,25] and nonlinear[21] programming methods have been used extensively to assign crews to particular shifts and days. Integer programming for cyclic shift assignments has been reduced to an algorithmic form simple enough for hand calculation.[26] For large problems, combined techniques have been developed. Decomposition of the linear program has been used to assign men and equipment to shifts while minimizing the work force required.[9] Network methods have been coupled with linear decomposition procedures to minimize internal costs [27] and to provide a heuristic basis for the simultaneous

scheduling of manpower and machines.[10] Goal programming (GP) has been used directly[28] and in conjunction with Markov processes to develop future manpower plans when objectives were in conflict.[29] When traditional GP packages faultered, a goal programming heuristic was designed to tackle multi-objective problems.[30] For extremely large formulations, heuristics and simulations have been used in tandem.[31]

In the present research, the snow removal personnel reassignment problem as stated in the previous section has been formulated as a multiobjective integer program. The model can be solved to generate the complete and precise tradeoff curve between the objectives of ***minimizing total travel distance*** and ***minimizing maximum travel distance*** in an orderly and systematic manner. The details of the model, which has been given the name SANTA (for Systematic Analysis of Noninferior Transfer Assignments), are presented in this section. A description of the model's solution procedure and an actual application of the model are presented in the following sections, respectively.

Consider the problem of assigning n workers to m site locations consistent with the discussion of the previous section. Let d_{ij} be the distance in miles from the residence of worker i to site location j along the route of shortest time-of-travel. Suppose that all d_{ij} values are known for all workers to all site locations. Let D be the maximum distance that any worker would be required to travel to his/her assigned site. We may now define:

$$N_i = \{j \mid d_{ij} \leq D\}$$

The set N_i is the set of sites j to which worker i *may* be assigned. This set is defined for each worker. Now define:

T_j = The total number of transfer personnel needed at site j $\quad j = 1,2,\ldots,m$

C = The total number of State vehicles available for winter assignment

$$x_{ij} = \begin{cases} 1, \text{ if worker i is assigned to unit location j;} & \forall i,\ j \in N_i \\ 0, \text{ otherwise} \end{cases}$$

$$A_{ij} = \begin{cases} 1, \text{ if the assignment of worker i to site j requires a vehicle;} & \forall i,\ j \in N_i \\ 0, \text{ otherwise} \end{cases}$$

Note that the value of A_{ij} may be computed directly as both the distances and the rule for assigning vehicles are known.

An objective function that seeks the smallest total travel distance resulting from a particular strategy for assigning workers may be written as follows:

$$\text{Minimize } Z = \sum_{i} \sum_{j \in N_i} d_{ij}\, x_{ij} \tag{1}$$

Any distance d_{ij} will only be "counted" if worker i is assigned to unit j; $x_{ij} = 1$. Total distance may be obtained by summing this term over all workers.

Several constraints are required to enforce personnel supply limitations and demand restrictions. To avoid assigning a single worker to more than one unit location, a set of constraints of the following form is required:

$$\sum_{j \in N_i} x_{ij} \leq 1 \qquad \forall i \tag{2}$$

The sum over all possible assignments for any single individual may not exceed a value of 1. If the total number of personnel to be assigned is equal to the total requirement for workers, the operator in this equation may be an equality. To insure that a sufficient number of workers is assigned to each unit location, a set of constraints of the following form must be included:

$$\sum_{i} x_{ij} \geq T_j \qquad \forall j \tag{3}$$

Finally, to avoid assigning workers in such a way that insufficient vehicles will be available, we must add the following constraint:

$$\sum_{i} \sum_{j \in N_i} A_{ij}\, x_{ij} \leq C \tag{4}$$

A vehicle will be issued only if a worker is assigned to a site requiring a vehicle and the total must not exceed C. The complete formulation is presented in Table 1.

The solution found by solving the model presented in Table 1 would be the assignment of workers to site locations such that the total (one-way) distance that all workers travel to work is as small as possible. As specified, the model does not address the issue of equity, and the solution provided by

Table 1: Model Formulation for Minimizing Total Distance

$$\text{Minimize } Z = \sum_{i} \sum_{j \in N_i} d_{ij}\, x_{ij} \tag{1}$$

$$\text{s.t.} \quad \sum_{j \in N_i} x_{ij} \leq 1 \qquad \forall i \tag{2}$$

$$\sum_{i} x_{ij} \geq T_j \qquad \forall j \tag{3}$$

$$\sum_{i} \sum_{j \in N_i} A_{ij}\, x_{ij} \leq C \tag{4}$$

$$x_{ij} = \{0,1\} \qquad \forall i, j \in N_i$$

where:

d_{ij} = The distance worker i would travel if assigned to unit location j (miles)

$N_i = \{j \mid d_{ij} \leq D\}$

D = Maximum allowable travel distance

T_j = Demand for workers at unit location j

C = Number of vehicles available for assignment

$$A_{ij} = \begin{cases} 1, & \text{if the assignment of worker i to unit j requires a vehicle} \\ 0, & \text{otherwise} \end{cases}$$

$$x_{ij} = \begin{cases} 1, & \text{if worker i is assigned to unit j} \\ 0, & \text{otherwise} \end{cases}$$

this model would likely contain large variances in assignment travel distances. Note also that it is possible for the problem to terminate infeasible if, for example, not enough workers are available to meet total demand, or if there are insufficient vehicles available for assignment, or if the distance restriction D is too small. However, if a feasible solution exists, an *optimal* assignment of workers to sites will be provided by the model. For the case where the constraint on available vehicles (Equation 4) is not binding, this solution represents that strategy requiring the largest number of vehicles; the utilization of one additional vehicle will not result in a strategy having a lower total distance measure.

The second objective imbeded in the snow removal personnel reassignment problem as stated in the previous section is to keep the maximum distance traveled by any worker as small as possible. This problem may also be formulated as a single-objective model. Let DMAX be that distance traveled by the worker who must travel the greatest distance to work. The objective is to find that reassignment strategy that makes this distance as small as possible within system constraints. Equation 1 is replaced by a new objective function:

$$\text{Minimize } Z = \text{DMAX} \tag{5}$$

In order to define DMAX as the maximum travel distance assigned to workers, the following set of constraints must be included:

$$\sum_{j \in N_i} d_{ij}\, x_{ij} \leq \text{DMAX} \qquad \forall\ i \tag{6}$$

No assigned travel distance d_{ij} will be larger than the value of DMAX which is being minimized. The rest of the model is identical to the formulation presented as Table 1. The complete formulation for minimizing maximum assigned travel distance is presented as Table 2.

The solution provided by solving the model presented in Table 2 would result in an assignment strategy where the distance traveled by the person traveling the greatest distance to work is as small as possible. Again, when the constraint on vehicles is not binding, the availability of one additional vehicle, will not produce a "better" solution in terms of maximum travel distance. The solutions of the model formulations presented in Tables 1 and 2 represent the endpoints of a tradeoff curve between the objectives of *minimizing total travel distance* and *minimizing maximum travel distance*. The details of the procedure used to generate the entire tradeoff curve are presented in the following section.

Table 2: Model Formulation for Minimizing Maximum Distance

$$\text{Minimize } Z = DMAX \tag{5}$$

$$\text{s.t.} \quad \sum_{j \in N_i} d_{ij} x_{ij} \leq DMAX \qquad \forall\, i \tag{6}$$

$$\sum_{j \in N_i} x_{ij} \leq 1 \qquad \forall i \tag{2}$$

$$\sum_{i} x_{ij} \geq T_j \qquad \forall j \tag{3}$$

$$\sum_{i} \sum_{j \in N_i} A_{ij} x_{ij} \leq C \tag{4}$$

$$x_{ij} = \{0,1\} \qquad \forall i,\, j \in N_i$$

where:

$DMAX$ = The maximum assigned travel distance

d_{ij} = The distance worker i would travel if assigned to unit location j (miles)

$N_i = \{j \mid d_{ij} \leq D\}$

D = Maximum allowable travel distance

T_j = Demand for workers at unit location j

C = Number of vehicles available fo assignment

$$A_{ij} = \begin{cases} 1, & \text{if the assignment of worker i to unit j requires a vehicle} \\ 0, & \text{otherwise} \end{cases}$$

$$x_{ij} = \begin{cases} 1, & \text{if worker i is assigned to unit j} \\ 0, & \text{otherwise} \end{cases}$$

Solution Procedure

A solution technique is proposed that will generate the complete and precise noninferior set between the objectives of *minimizing total travel distance* and *minimizing maximum travel distance*. The procedure is a variation of the "constraint method" of multiobjective programming.[32] The example discussed below involves the reassignment of 118 workers to 20 site

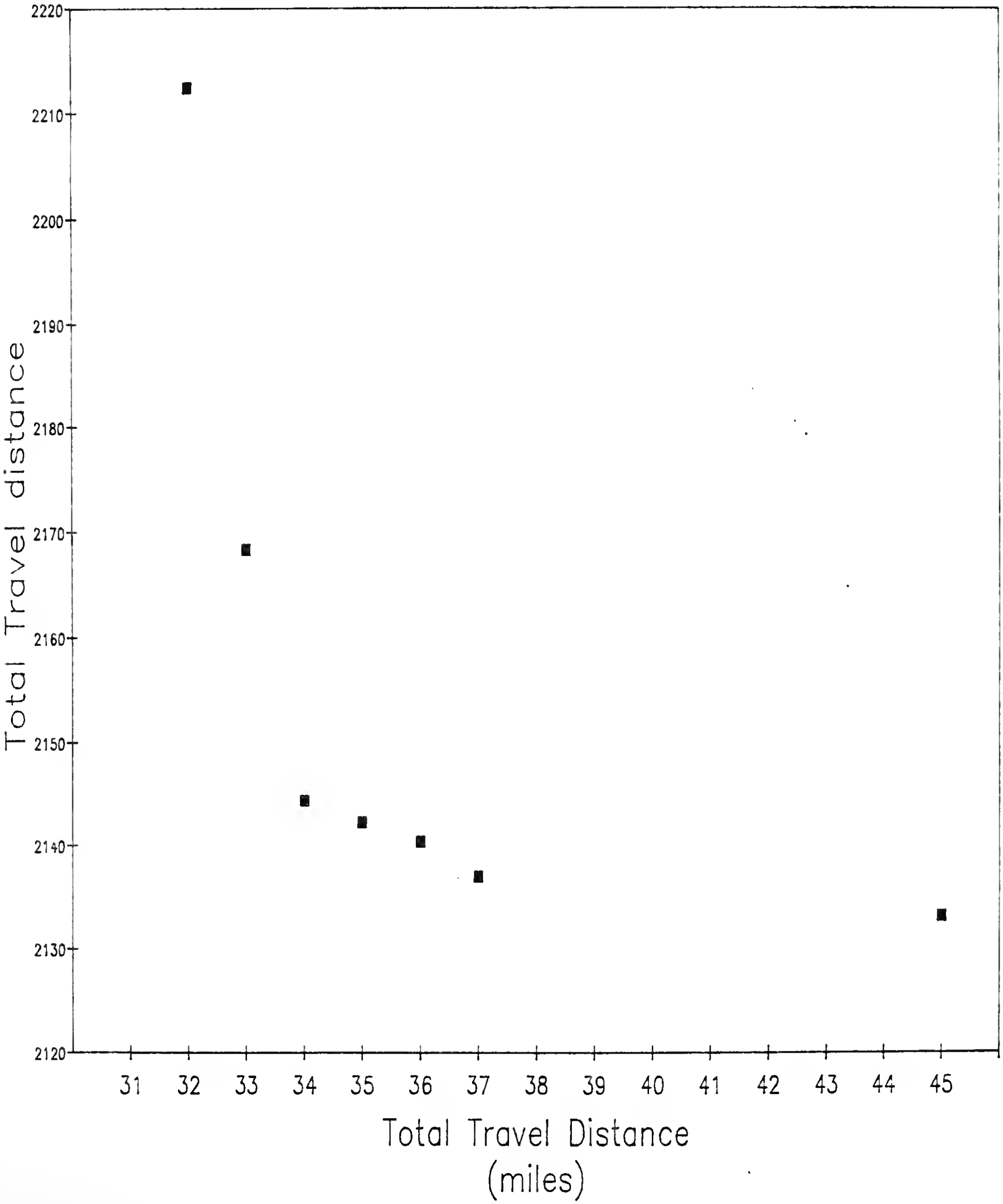
locations. The results of the model are shown by the tradeoff relationship presented in Figure 2.

The procedure begins by finding the *endpoints* of the noninferior solution set in objective space. These solutions correspond to the points labeled **A** and **B** in Figure 2. First, the model formulation presented in Table 1 - the formulation for minimizing maximum distance traveled - is solved as a single objective linear program. Experience has shown that the solution to this problem is integer ($x_{ij}=0,1$) in excess of 97 percent of the times it was solved. In fact, fractional solutions occurred only when the constraint on available vehicles (Equation 4) was binding at optimality; removing this restriction from the formulation yields the classic transportation problem of operations research. In cases where fractional solutions were encountered, only a few branch-and-bound iterations were needed to secure an integer solution. This solution corresponds to point **A** on the graph, and represents the solution with the smallest possible total distance measure. For this example, the smallest possible total distance of any assignment strategy would be 2,133 miles. Provided there does not exist an alternate optimal solution where the maximum distance traveled by any one individual is less than 45 miles, this solution is the true endpoint of the tradeoff curve. Because there does not exist a solution where the total travel distance is less than this amount, we need not consider solutions having a maximum distance in excess of 45 miles; any such solution would be *dominated* by this solution.

Next, the model presented in Table 2 - formulation for minimizing maximum travel distance - is solved, again, as a single objective problem. This solution for the sample problem is shown as point **B** on Figure 2. The smallest maximum travel distance possible for any feasible solution is 32 miles, and results from an assignment strategy requiring the workforce as a whole to travel a total of 2,212 miles to their work stations. Because there are no solutions with a shorter maximum distance measure (again, assuming there are no alternate optima with a lower total distance measure), we need not search for solutions having a longer total travel distance than that provided by this solution. Our search for noninferior solutions may be confined to the region between these endpoints.

The remainder of the noninferior solutions may be obtained by repeatedly solving a slightly modified version the formulation presented in Table 1. Recall that we defined the set N_i to be the set of job sites j to which

Figure 2. Multiobjective Tradeoff Curve: Minimize Total Travel Distance vs. Minimize Maximum Travel Distance



worker i might be assigned. In both previous formulations, this set depended on a specification of the parameter D; the maximum distance that any individual worker would be required to travel. Originally, this distance limitation was specified by the decision-maker consistent with the current policy for making winter personnel reassignments and was not meant to be an operational mechanism within the model. The smaller the value of D, the fewer the assignments that are possible and therefore, the fewer the number of decision variables x_{ij} that need to be defined. Consequently, by ranging the value of D between the smallest and the largest maximum distance measure (as provided by the initial endpoint solutions), and iteratively solving the formulation provided in Table 1, we can generate the remaining noninferior solutions.

For the sample problem, we know that there are no noninferior solutions requiring any individual to travel more than 45 miles to work. Furthermore, we know that there are no noninferior solutions where the greatest travel distance is less than 32 miles. Operationally, the definition of the set N_i in the formulation presented in Table 1 becomes

$$N_i = \{j \mid d_{ij} \leq D\} \qquad D = 33, 34, \ldots, 44$$

Each new value for D requires a separate model solution; each solution having a lower total distance measure than the preceding solution (as D increases), represents a true noninferior solution.

Using information provided by the initial endpoint solutions, we are able to reduce the size of the problem. Note that this is actually done external to the mathematical program and is practically achieved by a simple "filtering" of the input distance matrix. Generating the interior solutions is actually computationally "cheaper" than finding the endpoints.

Results and Discussion

The tradeoff curve generated by the procedure described above provides information about the degree of conflict between the two objectives being considered. Each point on the tradeoff curve represents a particular assignment of workers to site locations that is different from all other points on the curve. Furthermore, for each point on the curve, there does not exist

a "better" solution in terms of the stated objectives. The curve is thus an explicit indication of what must be given up in terms of one objective for a gain in terms of the other. For example, consider two noninferior solutions labeled C and D on the graph of Figure 2. By giving up one mile in terms of the maximum distance objective (from 33 miles to 34 miles) we are able to make an improvement in the total distance objective (from 2,168 miles to 2,144 miles). A similar analysis may be made between all noninferior solutions toward the identification of a "best compromise solution;" an exercise most appropriately conducted by the individual responsible for the ultimate reassignment decision.

Preliminary results from using SANTA to solve the snow removal personnel reassignment problem indicate that the model is computationally very efficient. Written entirely in FORTRAN, the model was originally designed to run on a Digital Equipment Corporation (DEC) VAX 11/780 under the UNIX 4.3BSD virtual memory operating system. For that environment, the model was partitioned into three separate modules for ease of prototyping. The data filtering/input generation component of the model had an executable size of 48K bytes and approximately three (wall clock) minutes were required to build an mpos input file. The size of the input file averaged 235K bytes. The linear program solution was provided by the eXperimental Math Programming (XMP) package[33] requiring 288Kbytes (compiled). An intermediate output file was written by XMP upon completion; the execution time for an optimal solution averaged six minutes. Finally, the third model element (~54K bytes) was used to prepart a formal solution report. When all three elements were combined in a UNIX command shell script to facilitate use, total solution times of as little as six minutes were experienced (although processing times in excess of one hour were not uncommon during periods of heavy system use).

Following a period of thorough testing and revision, the model was "ported" to a microcomputer environment. The following section of the report describes that version of the model and is intended as a user's guide for its future use.

Microcomputer Implementation of SANTA

HARDWARE REQUIREMENTS FOR SANTA

Specific, but readily available hardware is required to run the SANTA model. The model was designed to be executed on an IBM PC/AT or IBM PC/XT with 512 kilobytes of base memory (RAM) and a math co-processor. The common peripherals are assumed (monitor and keyboard) and, while not a necessity for SANTA to perform, a printer is highly recommended to receive full benefit of SANTA analysis.

The executable file for SANTA requires approximately 330K. When written to a double sided/double density floppy disk that contains a typical data file, the unused space on the disk is not large enough to accommodate a SANTA generated report of full size. For this reason, SANTA cannot be executed exclusively on a floppy drive unless the drive is "high capacity" rated. When a hard drive is present, SANTA should be copied from the floppy drive onto the hard disk (into the same directory as "data.in"). SANTA can then be executed from the hard drive and will write the output file into this common directory.

If a hard drive is not available, the user will need to use the "set" command to reconnect the output stream of SANTA. In other words, the file "output" will need to be written onto a disk in the secondary drive.

Due to this size limitation, the hardware must have either a floppy drive and a hard disk, two floppy drives, or a high capacity floppy drive. Notice also that the output stream cannot be redirected with a simple command-line redirect ('>'). If this operation is attempted, the standard output stream will also be redirected and all prompts, messages, and reports will go into the redirect file.

PREPARING THE INPUT DATA FILE

Before using SANTA, an appropriate data file must be constructed for the district (see Table 3.1). This file, which must always be called "data.in"

Table 3.1 A Sample Data Input File

20	LaPorte District							
NAME	3101	3102	3103	3104	3105	3201	3203	3204 . . .
DEMAND	10	13	12	7	11	4	5	. . .
ACOSTA, JUAN	47.9	56.6	60.2	49.2	51.8	30.9	28.3	. . .
ANDERSON, JAMES	27.8	32.9	44.1	33.1	32.1	10.0	26.3	. . .
BENNETT, DAVID	19.8	24.9	36.1	25.1	27.7	1.5	24.3	. . .
BORGMAN, DAVID	23.8	30.9	43.1	32.1	33.1	11.1	16.7	. . .
DISHMAN, RANDY	18.2	23.3	34.5	23.5	22.5	0.5	17.5	. . .
GORDON, JOHN	46.0	51.1	62.3	51.3	50.3	28.2	12.3	. . .
HARMON, STEPHEN	19.3	24.4	35.6	24.6	23.6	1.5	24.3	. . .
HELTON, JIMMY	19.8	24.9	36.1	25.1	27.7	1.5	24.3	. . .
HERBERT, MICH	42.4	47.4	58.7	47.7	46.6	23.6	21.8	. . .
JOHNSON, RONALD	24.8	29.9	41.1	30.1	29.1	6.0	28.6	. . .
JOHNES, JAMES	19.8	24.9	36.1	25.1	27.7	1.5	24.3	. . .
JONES, MARK	18.2	23.3	34.5	23.5	22.5	0.5	17.5	. . .
KINNEY, DANNY	22.6	31.3	35.9	23.8	26.5	5.3	27.8	. . .
KRAMER, THOMAS	25.8	30.9	42.1	31.1	30.1	5.0	30.3	. . .
NOFZIGER, DANNY	19.8	24.9	36.1	25.1	27.7	1.5	24.3	. . .
PERRY, JEFFERY	29.5	34.7	45.9	34.8	33.8	12.0	29.6	. . .
SNEDGAR, DAVID	43.0	48.1	59.3	48.3	47.3	25.2	16.4	. . .
SPARKS, MARTY	27.8	32.9	44.1	33.1	32.1	10.0	24.3	. . .
WARD, WALTER	32.9	38.0	49.2	38.2	37.2	15.1	22.5	. . .
HANCOCK, ERNEST	44.9	53.6	57.2	46.2	48.8	27.8	25.3	. . .
SADLER, LEX	45.3	50.4	61.7	50.7	49.6	27.6	16.8	. . .
HAMM, DIANE	18.2	23.3	34.5	23.5	22.5	0.5	17.5	. . .
JACKSON, JEFFERY	31.9	37.0	48.2	37.2	36.2	14.1	31.5	. . .
KELTNER, LOREN	19.8	24.9	36.1	25.1	27.7	0.4	24.3	. . .
NUNLEY, MICHAEL	48.9	57.1	53.2	36.4	52.3	34.9	53.2	. . .
PITCHER, KENT	18.2	23.3	34.5	23.5	22.5	0.5	17.5	. . .
. .	.	.	.	.	.	.	.	. . .
. .	.	.	.	.	.	.	.	. . .
. .	.	.	.	.	.	.	.	. . .

to remain separated from user input, contains most of the information that SANTA will use to develop a solution. Although the accuracy of the data can vary slightly, the location and format of the data are critical.

The lines of the data file can be grouped into four categories. The first line of the file is called the "Parameter Line" because it allows the districts to contain different numbers of units and to specify a portion of the report title. The number of units in the district is placed in columns one through five. (Refer to Table 3.2, Quick Reference for "data.in" and Table 3.3, A Skeletal Data File). It is good practice to right justify all data, although not absolutely necessary.

Table 3.2 Quick Reference for "data.in" Format

```
For row 1:  the PARAMETER row,

¦   ¦  --  columns 1-5:  number of units in the subdistrict
     ¦.............................¦  --  columns 6-35:  title

Example:
   19       LaPorte District

For row 2:  the UNIT NAMES row,

¦                     ¦  --  columns 1-23:  unused
                       ¦   ¦  --  columns 24-28,
                            ¦   ¦  -- columns 29-33, (etc.):
                                       unit names (character!)

Example:
  NAME                  4101 4102 4103 4201 4202 4203 4301 ...

For row 3:  the DEMAND row,

¦                     ¦  --  columns 1-23:  unused
                       ¦   ¦  --  columns 24-28,
                            ¦   ¦  -- columns 29-33, (etc.):
                                       demand at each unit

Example:
 DEMAND                   12    6    8    4    2    0    5 ...

For rows 4 and on:  the INDIVIDUAL rows,

¦                ¦  --  columns 1-18:  employee name
```

```
                              |    |  --  columns 19-23:  employee "fix"
                                   |    |  --  columns 24-28,
                                        |    |  -- columns 29-33, (etc.):
                                                    distance (miles)

Example:
Brown K                       12.0 23.0 26.0 70.0 68.0 87.0 22.0 ...
```

The second field of the Parameter Line, running from columns 6 through 35, is used to specify a secondary title for reports. It is recommended that each district use their common name (LaPorte District, Greenfield District, etc.), but this field can remain blank without deleterious affects. Notice that the field is 30 columns wide and the selected title should be centered within this field. Characters are read literally, therefore upper and lower case will appear on the report as they do on the Parameter Line.

The second line of "data.in" provides the names of the units and is therefore called the "Name Line". Although the first 23 columns of this line are not used, this area can hold a label for the line (eg, "NAME"). Beginning in column 24, five-column blocks are associated with individual units. This segmentation will remain in effect through all the remaining lines of the data file.

On the Name Line, these blocks contain unit identifiers which are interpreted by SANTA as character strings. For example, the first unit name found in Tables 3.2 and 3.3 is "b4101". Notice that the string is right justified: the name begins with the space (represented by a small "b"). Appropriate spacing of four character unit names is critical to the proper generation of reports. In addition, the ordering of these names is important. As the "Subdistrict Report" is being generated, subdistrict "breaks" are interpreted on the basis of a change in third character for subsequent unit names; the assumed Department of Highways standard. For example, if the Names Line is " 4101 4203 4102 ...", SANTA will produce a subdistrict report for Subdistrict 1 (with only unit 4101), Subdistrict 2 (with only unit 4203), and Subdistrict 1 again (with unit 4102 and any 4100 units immediately

Table 3.3 A Skeletal Data File

```
    19        LaPorte District
   NAME                   4101 4102 4103 4201 4202 4203 ...
  DEMAND                    12    6    8    4    2    0 ...
Allen K
Alverez A
Arens B
Armstrong D
Atkinson T
Baillieul R
Baker D
Barta M
Bell B
Berg K
Bohm D
Bradfield R
Brown K                   12.0 23.0 26.0 70.0 68.0 87.0 ...
Cain E
(...)
```

following).

Line three of the data file is called the "Demand Line" for obvious reasons. As with the Names Line, the Demand Line allows the use of the first 23 columns for a label. The five-column blocks under individual unit headings specify the person-power requirement at each of the units. It is recommended that demand numbers be right justified in these fields and that zero demand should be explicit (place a "0" in the demand field). These numbers may require annual adjustment and it is important to remember that SANTA will NOT perform unless total demand is equal to the number of people available.

The fourth and last class of data line is called the "Employee Line" and will be used for all the employee information. The first eighteen columns of an Employee Line contain the individual's name. Upper case, lower case or mixed case names are at the discretion of the user. The names need not be in any particular order: SANTA will alphabetize all output lists. However, the user should be warned that SANTA will arrange these lists using characters from the beginning of the name field. Therefore, names should be in "Last, First" format to avoid lists which start with "Abby" and end with "Zeke".

Columns 19 through 23 of Employee Lines can be used to "fix" individual personnel to specific units. The five character string within these columns must match a unit name precisely for a proper fix to occur. If unit names begin with a blank, the fix string must also begin with a blank. A fix will be attempted when ANY non-blank character appears in column 20. Currently, all faulted fixes (non-blank column 20 but SANTA unable to match with a unit name) are reported to the user during the execution of SANTA and subsequently ignored to allow a solution attempt.

The five-column blocks on Employee Lines are used to specify the one-way driving distance (miles) from the individual's residence to the indicated site. It is recommended that distances be limited to four "characters" and right justified in these fields (eg, 24.8 101. 2.9) to keep column blocks visibly separated. Accuracy of these distance quantities may vary slightly. When the distance is greater than 50 miles or so, rounding to the nearest 5 miles may prove satisfactory. Distances of less than 50 miles should be accurate to the nearest 2 miles whenever possible, but accuracy requirements will, for the most part, be determined by the individuals who generate this distance information.

Annual maintenance of "data.in" can be performed with any standard editor. Employee Lines can be adjusted (name or residence change, etc.), deleted (individual removed from transferable list), or added (new transferables). Remember that SANTA alphabetizes reports internally. Laborious editing to maintain order in the data file is not necessary but may prove beneficial when this data maintenance function is performed.

This concludes the specifications for "data.in". As an additional tip for those building a data file from scratch: use the sample "data.in" provided with SANTA as a foundation. Making a copy of this file for a "starting point" will provide initial column locations. Print the file out before annual

execution of SANTA to visually inspect column alignment. As mentioned earlier, location of the data elements in the file is highly critical.

USING THE SANTA MODEL

Once the data file "data.in" has been developed, the user is prepared to run the SANTA model. When a proper environment has been established the user initiates SANTA by typing "santa" (see Table 4).

Table 4. Running the SANTA Model

```
C>  santa

     ENTER MAXIMUM MILEAGE:  35

     ENTER NUMBER OF VEHICLES AVAILABLE:  65

  (slight delay)

     PROPER FORMULATION, SANTA RUNNING
          118 PEOPLE INVOLVED
          878 VARIABLES
          139 CONSTRAINTS

     EXPECTED SOLUTION TIME:  APPROX. 15 MINUTES...

  (long delay)

      --> AN ANSWER HAS BEEN FOUND <--

     REPORT SELECTION:

          1.  MANAGEMENT REPORT ONLY

          2.  ASSIGNMENTS SECTION ONLY

          3.  1, 2, and ALTERNATES

          4.  SUBDISTRICT SUMMARIES

          5.  THE WORKS

          6.  SAVE NO OUTPUT
```

```
PLEASE ENTER YOUR SELECTION NUMBER:  5

FORMAT SELECTION:

      1.  SUITABLE FOR SCREENING (default)

      2.  HARDCOPY (special format)

PLEASE ENTER YOUR SELECTION NUMBER:  2

OUTPUT being written to the file "output"

C>
```

The SANTA program will first ask the user to enter the "maximum mileage" standard for this run. If the user responds with a number larger than sixty, SANTA will default to a sixty mile maximum. SANTA will then ask for the "number of vehicles available". Once the user has entered this number, SANTA begins inspecting the data file. If total demand does not equal the number of people available, SANTA will report both of these values and stop, returning the user to MS-DOS.

If the data file passes demand checking, SANTA will formulate a linear program and report the number of people involved in the current problem for visual inspection. At this point, SANTA also reports the number of variables and number of constraints involved in the current run. These numbers can have particular significance for the experienced user; the number of constraints will always equal the number of people involved plus the number of units with nonzero demand plus one. The number of variables will vary with different mileage standards, increasing as the maximum allowed distance is increased. This number will often determine how much difficulty SANTA has in arriving at a solution, or whether a solution can be found at all. Software limits impose restrictions on the number of variables which will be allowed, but problems which are too large to formulate will not ordinarily make it to this point.

Assuming a proper formulation was constructed, SANTA remarks to the user that there will be a delay of "approximately fifteen minutes". The

user should bear in mind that this number (15) is hard coded, and not calculated from the size of the problem. Actual run time will generally be a bit longer. After the first few local runs, the user should have a fairly good idea of the actual delay time.

Once the number crunching is completed, SANTA will report to the user's monitor again. If a solution could not be found, SANTA will announce the difficulty and add a suggestion for improving the chances of finding a solution ("increase mileage standard", etc.). Otherwise, SANTA will present the Report Selection menu and the user will be asked to select a reporting "depth" by entering a number between one and six. Entries outside this range will produce and error message and bring the Report Selection menu up again. If selection six is chosen ("save no output"), SANTA will terminate and return the user to MS-DOS.

After the report level has been specified, SANTA will prompt the user for a format selection. Format type two is suitable for the IBM Quietwriter, Proprinter, and other IBM compatible printers (double width lines, graphics characters, etc.). Format type one is more appropriate for viewing on the monitor or printing on incompatible printers, although type two is "monitor acceptable". Any user entry other than "2" will default to format type one.

If the user has come this far, SANTA will remark that output is being written to the file "output" before returning the user to DOS. This is an important point: the current version of SANTA ALWAYS writes any pertinent output to this file. Therefore, the user should carefully archive solutions by moving or copying the "output" file (different directory, different name, etc.). Subsequent SANTA runs will overwrite any file called "output" in the local directory. This is the primary reason for Report Selection item number six, to allow the user a "graceful" exit without destroying the results of a prior run.

Reports generated by SANTA will be similar to those in Table 5. The various sections of the report are page separated and individually labeled for the user's convenience.

INDIANA DEPARTMENT OF HIGHWAYS

Laporte District

DISTANCE SUMMARY	
MAXIMUM ALLOWED =	38.0
TOTAL DISTANCE =	1853.1
AVERAGE DISTANCE =	14.8
MAXIMUM DISTANCE =	38.0
DEV DISTANCE =	38.0

VEHICLE SUMMARY	
STATE VEHICLES:	
NUMBER AVAILABLE:	55
TOT. ALLOCATED =	55
TOTAL DISTANCE =	1405.0
AVERAGE DISTANCE =	25.5
PRIVATELY OWNED:	
TOTAL DISTANCE =	448.1
AVERAGE DISTANCE =	6.4

ONE-WAY DISTANCE BREAKDOWN

TOTAL	INTERVAL (miles)	0 5 10 15 20 25 30 35 40 45 50
(36)	0 - 5	PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
(17)	5 - 10	PPPPPPPPPPPPPPPPP
(17)	10 - 15	PPPPPPPPPPPPPPPP*
(18)	15 - 20	P*****************
(13)	20 - 25	*************
(6)	25 - 30	******
(9)	30 - 35	*********
(9)	35 - 40	*********

0 5 10 15 20 25 30 35 40 45 50

NUMBER OF EMPLOYEES IN EACH INTERVAL

P - PERSONAL VEHICLE
* - STATE VEHICLE

Table 5. Output Generated by SANTA

INDIANA DEPARTMENT OF HIGHWAYS

Laporte District

ALTERNATE ASSIGNMENTS

Baillieul R	to UNIT 4301	Lietzan W	to UNIT 4501
Bell B	to UNIT 4301	Ludwig J	to UNIT 4502
Carey R	to UNIT 4101	Rynearson K	to UNIT 4103
Ewing R	to UNIT 4102	Standifer L	to UNIT 4702
Gastineau D	to UNIT 4402	Stigen L	to UNIT 4102
Kinsey M	to UNIT 4202	Strom J	to UNIT 4701
Leinbach E	to UNIT 4501	Weatherwax K	to UNIT 4201

Table 5. (cont.) Output Generated by SANTA

INDIANA DEPARTMENT OF HIGHWAYS

Laporte District

ASSIGNMENT REPORT

EMPLOYEE	UNIT	MILES	EMPLOYEE	UNIT	MILES
* Allen K	4102	19.0	* Howard H	4502	21.0
Alverez A	4701	9.0	* Hudson M	4102	34.0
Arens B	4103	4.0	* Insco F	4501	28.0
* Armstrong D	4702	24.0	Jacks R	4103	1.0
Atkinson T	4202	2.0	Jackson J	4701	9.0
Baillieul R	4602	1.0	James L	4601	15.0
Baker D	4302	7.0	* Johnson B	4702	32.0
Barta M	4701	11.0	Johnson R	4701	11.0
* Bell B	4302	29.0	Jones J	4701	9.0
* Berg K	4702	37.0	Jones T	4701	9.0
* Bohm D	4102	34.0	* Kemp J	4702	16.0
Bradfield R	4702	16.0	* Kinsey M	4201	22.0
Brown K	4101	12.0	Kroening R	4103	1.0
* Cain E	4402	21.0	* Kruzick C	4102	34.0
* Carey R	4302	29.0	* Lamb M	4301	36.0
Chrzan R	4302	3.0	Lane K	4302	12.0
* Collins M	4702	24.0	Larson C	4701	1.0
Crane S	4101	1.0	Leinbach E	4102	10.0
* Dalka C	4501	32.0	* Lemay R	4502	21.0
Donovan P	4302	2.0	Lemons E	4701	10.0
Edging S	4301	4.0	Lestinsky S	4101	5.0
* Egolf B	4702	27.0	* Lietzan W	4502	16.0
* Ekovich A	4502	15.0	Link H	4101	1.0
* England W	4502	21.0	* Lorenz R	4501	37.0
Epley B	4502	5.0	Lotter R	4101	1.0
* Ewing R	4402	34.0	Ludwig J	4101	2.0
* Fagner M	4102	34.0	Lynn W	4101	0.0
Fleming L	4103	5.0	Mangus R	4301	9.0
Ford K	4402	0.1	Marker T	4302	12.0
* Fosler R	4702	37.0	* Marlin C	4702	33.0
Franks R	4701	11.0	* Marshall W	4501	37.0
* Galvas N	4302	20.0	Martin R	4702	10.0
Garcia J	4402	1.0	* Mathew J	4702	37.0
* Gastineau D	4702	38.0	* Mattocks J	4702	33.0
Gray D	4701	9.0	McCarver D	4201	2.0
* Grubb J	4702	18.0	McClellan F	4701	5.0
* Hammons J	4502	21.0	* McGuire M	4103	17.0
* Hannigan L	4702	17.0	Miller M	4702	9.0
Hatcher D	4202	1.0	* Mougin M	4501	36.0
Hathaway R	4702	9.0	O'Haver R	4302	13.0
Heidorn M	4601	15.0	* O'Neil T	4702	16.0
* Henrichs G	4501	28.0	Panos W	4101	0.0
* Henry L	4502	21.0	Parker J	4101	1.0
Horvath L	4302	8.0	* Poncher J	4702	20.0
Houston M	4402	13.0	Pope J	4502	4.0

Table 5. (cont.) Output Generated by SANTA

INDIANA DEPARTMENT OF HIGHWAYS

Laporte District

ASSIGNMENT REPORT (page 2)

	EMPLOYEE	UNIT	MILES		EMPLOYEE	UNIT	MILES
	Porvaznik T	4701	9.0	*	Strom J	4702	20.0
	Redman R	4103	12.0		Swartz K	4402	1.0
	Reynolds L	4701	2.0	*	Teel R	4201	23.0
	Rogers J	4702	11.0		Thompson T	4701	7.0
*	Roorda J	4702	16.0	*	Tobey R	4301	25.0
*	Ropp W	4501	30.0		Trask R	4702	10.0
*	Rouch B	4301	36.0		Vermilyer R	4101	10.0
	Rowland D	4402	15.0	*	Walter M	4702	19.0
	Rundzaitis A	4502	5.0	*	Weatherwax K	4602	16.0
*	Rynearson K	4502	21.0		Weiler D	4101	0.0
	Schafer P	4302	5.0		White D	4502	3.0
*	Schweitzer D	4103	25.0		White J	4601	15.0
	Shive C	4701	1.0		Wilke T	4103	3.0
	Smith D	4101	1.0		Wright J	4402	1.0
	Standifer L	4701	14.0	*	Ziulkowski M	4702	16.0
*	Stewart W	4702	16.0	*	Ziulkowski P	4702	19.0
	Stigen L	4601	1.0		Zolcak R	4702	11.0
	Crane S	4101	1.0				

Table 5. (cont.) Output Generated by SANTA

INDIANA DEPARTMENT OF HIGHWAYS

Laporte District

SUMMARY FOR SUBDISTRICT 4100

UNIT: 4101 DEMAND: 12

1.	Brown K	12.0
2.	Crane S	1.0
3.	Lestinsky S	5.0
4.	Link H	1.0
5.	Lotter R	1.0
6.	Ludwig J	2.0
7.	Lynn W	0.0
8.	Panos W	0.0
9.	Parker J	1.0
10.	Smith D	1.0
11.	Vermilyer R	10.0
12.	Weiler D	0.0

UNIT: 4102 DEMAND: 6

1.	* Allen K	19.0
2.	* Bohm D	34.0
3.	* Fagner M	34.0
4.	* Hudson M	34.0
5.	* Kruzick C	34.0
6.	Leinbach E	10.0

UNIT: 4103 DEMAND: 8

1.	Arens B	4.0
2.	Fleming L	5.0
3.	Jacks R	1.0
4.	Kroening R	1.0
5.	* McGuire M	17.0
6.	Redman R	12.0
7.	* Schweitzer D	25.0
8.	Wilke T	3.0

SUBDISTRICT LISTING

1.	Allen K	4102
2.	Arens B	4103
3.	Bohm D	4102
4.	Brown K	4101
5.	Crane S	4101
6.	Fagner M	4102
7.	Fleming L	4103
8.	Hudson M	4102
9.	Jacks R	4103
10.	Kroening R	4103
11.	Kruzick C	4102
12.	Leinbach E	4102
13.	Lestinsky S	4101
14.	Link H	4101
15.	Lotter R	4101
16.	Ludwig J	4101
17.	Lynn W	4101
18.	McGuire M	4103
19.	Panos W	4101
20.	Parker J	4101
21.	Redman R	4103
22.	Schweitzer D	4103
23.	Smith D	4101
24.	Vermilyer R	4101
25.	Weiler D	4101
26.	Wilke T	4103

Table 5. (cont.) Output Generated by SANTA

INDIANA DEPARTMENT OF HIGHWAYS

Laporte District

SUMMARY FOR SUBDISTRICT 4200

UNIT: 4201 DEMAND: 4

1.	* Kinsey M	22.0
2.	McCarver D	2.0
3.	* Stonebraker G	17.0
4.	* Teel R	23.0

UNIT: 4202 DEMAND: 2

1.	Atkinson T	2.0
2.	Hatcher D	1.0

UNIT: 4203 DEMAND: 0

SUBDISTRICT LISTING

1.	Atkinson T	4202
2.	Hatcher D	4202
3.	Kinsey M	4201
4.	McCarver D	4201
5.	Stonebraker G	4201
6.	Teel R	4201

Table 5. (cont.) Output Generated by SANTA

INDIANA DEPARTMENT OF HIGHWAYS

Laporte District

SUMMARY FOR SUBDISTRICT 4300

UNIT: 4301 DEMAND: 5

1.		Edging S	4.0
2.	*	Lamb M	36.0
3.		Mangus R	9.0
4.	*	Rouch B	36.0
5.	*	Tobey R	25.0

UNIT: 4302 DEMAND: 11

1.		Baker D	7.0
2.	*	Bell B	29.0
3.	*	Carey R	29.0
4.		Chrzan R	3.0
5.		Donovan P	2.0
6.	*	Galvas N	20.0
7.		Horvath L	8.0
8.		Lane K	12.0
9.		Marker T	12.0
10.		O'Haver R	13.0
11.		Schafer P	5.0

UNIT: 4303 DEMAND: 0

SUBDISTRICT LISTING

1.	Baker D	4302
2.	Bell B	4302
3.	Carey R	4302
4.	Chrzan R	4302
5.	Donovan P	4302
6.	Edging S	4301
7.	Galvas N	4302
8.	Horvath L	4302
9.	Lamb M	4301
10.	Lane K	4302
11.	Mangus R	4301
12.	Marker T	4302
13.	O'Haver R	4302
14.	Rouch B	4301
15.	Schafer P	4302
16.	Tobey R	4301

Table 5. (cont.) Output Generated by SANTA

INDIANA DEPARTMENT OF HIGHWAYS

Laporte District

SUMMARY FOR SUBDISTRICT 4400

UNIT: 4401 DEMAND: 0

UNIT: 4402 DEMAND: 8

1.	* Cain E	21.0
2.	* Ewing R	34.0
3.	Ford K	0.1
4.	Garcia J	1.0
5.	Houston M	13.0
6.	Rowland D	15.0
7.	Swartz K	1.0
8.	Wright J	1.0

UNIT: 4403 DEMAND: 0

SUBDISTRICT LISTING

1.	Cain E	4402
2.	Ewing R	4402
3.	Ford K	4402
4.	Garcia J	4402
5.	Houston M	4402
6.	Rowland D	4402
7.	Swartz K	4402
8.	Wright J	4402

Table 5. (cont.) Output Generated by SANTA

INDIANA DEPARTMENT OF HIGHWAYS

Laporte District

SUMMARY FOR SUBDISTRICT 4500

UNIT: 4501 DEMAND: 7

1.	*	Dalka C	32.0
2.	*	Henrichs G	28.0
3.	*	Insco F	28.0
4.	*	Lorenz R	37.0
5.	*	Marshall W	37.0
6.	*	Mougin M	36.0
7.	*	Ropp W	30.0

UNIT: 4502 DEMAND: 12

1.	*	Ekovich A	15.0
2.	*	England W	21.0
3.		Epley B	5.0
4.	*	Hammons J	21.0
5.	*	Henry L	21.0
6.	*	Howard H	21.0
7.	*	Lemay R	21.0
8.	*	Lietzan W	16.0
9.		Pope J	4.0
10.		Rundzaitis A	5.0
11.	*	Rynearson K	21.0
12.		White D	3.0

SUBDISTRICT LISTING

1.	Dalka C	4501
2.	Ekovich A	4502
3.	England W	4502
4.	Epley B	4502
5.	Hammons J	4502
6.	Henrichs G	4501
7.	Henry L	4502
8.	Howard H	4502
9.	Insco F	4501
10.	Lemay R	4502
11.	Lietzan W	4502
12.	Lorenz R	4501
13.	Marshall W	4501
14.	Mougin M	4501
15.	Pope J	4502
16.	Ropp W	4501
17.	Rundzaitis A	4502
18.	Rynearson K	4502
19.	White D	4502

Table 5. (cont.) Output Generated by SANTA

INDIANA DEPARTMENT OF HIGHWAYS

Laporte District

SUMMARY FOR SUBDISTRICT 4600

UNIT: 4601 DEMAND: 4

1.	Heidorn M	15.0
2.	James L	15.0
3.	Stigen L	1.0
4.	White J	15.0

UNIT: 4602 DEMAND: 2

1.	Baillieul R	1.0
2.	* Weatherwax K	16.0

UNIT: 4603 DEMAND: 0

SUBDISTRICT LISTING

1.	Baillieul R	4602
2.	Heidorn M	4601
3.	James L	4601
4.	Stigen L	4601
5.	Weatherwax K	4602
6.	White J	4601

Table 5. (cont.) Output Generated by SANTA

INDIANA DEPARTMENT OF HIGHWAYS

Laporte District

SUMMARY FOR SUBDISTRICT 4700

UNIT: 4701 DEMAND: 16

1.	Alverez A	9.0
2.	Barta M	11.0
3.	Franks R	11.0
4.	Gray D	9.0
5.	Jackson J	9.0
6.	Johnson R	11.0
7.	Jones J	9.0
8.	Jones T	9.0
9.	Larson C	1.0
10.	Lemons E	10.0
11.	McClellan F	5.0
12.	Porvaznik T	9.0
13.	Reynolds L	2.0
14.	Shive C	1.0
15.	Standifer L	14.0
16.	Thompson T	7.0

UNIT: 4702 DEMAND: 28

1.	* Armstrong D	24.0
2.	* Berg K	37.0
3.	Bradfield R	16.0
4.	* Collins M	24.0
5.	* Egolf B	27.0
6.	* Fosler R	37.0
7.	* Gastineau D	38.0
8.	* Grubb J	18.0
9.	* Hannigan L	17.0
10.	Hathaway R	9.0
11.	* Johnson B	32.0
12.	* Kemp J	16.0
13.	* Marlin C	33.0
14.	Martin R	10.0
15.	* Mathew J	37.0
16.	* Mattocks J	33.0
17.	Miller M	9.0
18.	* O'Neil T	16.0
19.	* Poncher J	20.0
20.	Rogers J	11.0
21.	* Roorda J	16.0
22.	* Stewart W	16.0
23.	* Strom J	20.0
24.	Trask R	10.0
25.	* Walter M	19.0
26.	* Ziulkowski M	16.0
27.	* Ziulkowski P	19.0
28.	Zolcak R	11.0

SUBDISTRICT LISTING

1.	Alverez A	4701
2.	Armstrong D	4702
3.	Barta M	4701
4.	Berg K	4702
5.	Bradfield R	4702
6.	Collins M	4702
7.	Egolf B	4702
8.	Fosler R	4702
9.	Franks R	4701
10.	Gastineau D	4702
11.	Gray D	4701
12.	Grubb J	4702
13.	Hannigan L	4702
14.	Hathaway R	4702
15.	Jackson J	4701
16.	Johnson B	4702
17.	Johnson R	4701
18.	Jones J	4701
19.	Jones T	4701
20.	Kemp J	4702
21.	Larson C	4701
22.	Lemons E	4701
23.	Marlin C	4702
24.	Martin R	4702
25.	Mathew J	4702
26.	Mattocks J	4702
27.	McClellan F	4701
28.	Miller M	4702
29.	O'Neil T	4702
30.	Poncher J	4702
31.	Porvaznik T	4701
32.	Reynolds L	4701
33.	Rogers J	4702
34.	Roorda J	4702
35.	Shive C	4701
36.	Standifer L	4701
37.	Stewart W	4702
38.	Strom J	4702
39.	Thompson T	4701
40.	Trask R	4702
41.	Walter M	4702
42.	Ziulkowski M	4702
43.	Ziulkowski P	4702
44.	Zolcak R	4702

Table 5. (cont.) Output Generated by SANTA

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